pellucidæ; interiores petaloideæ, tenerrimæ. Stamina tria; filamenta gracilia, antheris longiora; antheræ obovatæ, compressæ, loculis granulis pollinis inter se conglomeratis repletis, dehiscentia ignota. Stigmata tria, bipartita (?), cruribus recurvis perianthii laciniis exterioribus duplo longioribus.

Obs. Elodea canadensis (Michx.) a specie supra descripta differt, ob verba auctoris in delineatione characteris generici, "ovarium ad caulem sessile." Inde stirps ad *Anacharidem canadensem* (Planch.) verosimiliter recte referta.

EXPLANATION OF PLATE VIII.

Anacharis Alsinastrum, natural size, with a detached flower showing its very long tube.

Note.—The flower, the only one obtained, is doubtless imperfect, by wanting the third stigma.

a. A whorl of leaves.
b. Summit of the sheath.
c. A female flower.
d. Stigmatic fringe.
} Magnified.

We are indebted to Mr. J. W. Salter for the beautiful drawing, made for the 'Supplement to English Botany,' from which our plate is engraved.

IX.—*On the Anatomy of* Eolis, *a genus of Mollusks of the order* Nudibranchiata.

By Albany Hancock and Dennis Embleton, M.D., F.R.C.S.E., Lecturer on Anatomy and Physiology in the Newcastle-upon-Tyne School of Medicine.

[Continued from vol. xv. p. 88.]

[With two Plates.]

Organs of Generation.

For the sake of convenience we will treat of these in the following order:—

1st. Male apparatus: testis and penis, and mechanism for intromission and retraction.

2nd. Female apparatus: ovary with oviduct and accessory glands.

3rd. Complementary androgynous organs: spermatheca and its channels.

The generative organs lie for the most part beneath all the other viscera, and occupy the greatest part of the cavity of the body. The ovary at the season of reproduction nearly fills up the posterior half of the body, and the median line divides it into two almost symmetrical parts.

The other organs lie in front of the ovary, and extend as far forwards as the sides of the buccal mass; they are unsymmetrical,

being placed chiefly on the right side, partially covered by the stomach which dips down on the median line between them and the posterior border of the buccal mass; all their outlets leading to a common orifice, which is situated on the right side between the terminations of the rows of papillæ and the margin of the foot, and a short way behind the dorsal tentacles.

This orifice exists at the depressed apex of a small conical nipple or papilla, formed by a projecting and slightly puckered fold of skin, and is readily seen. When this orifice is laid open, a vestibule, or small cavity, is discovered, on the inner wall of which are three perforations, two being easily discovered, surrounded by a wrinkled and projecting border of skin, one directly in front of the other; a third may be detected with some pains among the folds around the posterior opening, and at its anterior part. Of the two openings first mentioned the anterior leads to the male apparatus; the posterior, which is the largest of the three, leads to the female organs; and the third, by far the smallest, leads to the spermatheca. Such is the state of the external parts in their most perfect state of contraction, after death, or in the absence of sexual excitement during life. But during the breeding season it is often found that the vestibule is obliterated by the protrusion outwardly of its inner wall, and then the anterior aperture is replaced, as it were, by a curved conical projection with its concavity posteriorly. This projection is the penis in a partial state of protrusion, and directly behind the base of it is seen the large female orifice, and immediately within this exists the third and smallest opening.

To obtain a complete view of the internal generative organs, it is necessary to remove all the other viscera. The ovary, Pl. III. fig. 1 *d*, is then seen as before mentioned, filling nearly the whole of the posterior part of the cavity of the body. It is of a pale yellow colour, lobulated and granular, broad and thick in front, tapering behind. Its anterior surface is concave, and moulded upon the parts directly in front. These are two large, delicate, semipellucid, convex and somewhat rounded lobes of a gland accessory to the female parts, Pl. III. fig. 1 *g g*, which we will call the mucus-gland, since it appears to secrete the mucus-like envelope of the ova, as will afterwards be seen.

These lobes are continuous with each other below, but above there is a deep fissure between them running from behind forwards. At the posterior end of the fissure lies the convoluted part of the oviduct, fig. 1 *f*, which runs forwards into the fissure. Under the convolutions of the oviduct lies the spermatheca with its duct, fig. 1 *h*, *i*. At the anterior end of the fissure, and resting on the front of the right lateral lobe of the mucus-gland, lies a long pale-flesh-coloured much-convoluted tube, fig. 1 *c*, the testis, one

end of which passes backwards into the fissure and communicates with the oviduct, the other enters the apex of a conical projection, fig. 1 *a*, which it will be seen is the retracted male intromittent organ.

Having given the above general notice of the parts as they are seen on being laid bare, and partially drawn asunder, we now proceed to a more particular description of the same after they have been carefully dissected, premising that the description, as well as the general notice, is taken from *E. papillosa*, except where it is otherwise expressed.

1st. Male apparatus: we have already said, that of the external orifices, the male, fig. 2 *d'*, lies in front of the other two. When this orifice is laid open in a specimen that has the parts fully retracted into the body, we find a short canal opening almost immediately into a pretty large sac, fig. 7 *a*, which is nearly filled by a somewhat egg-shaped body *c*, projecting into its interior. The sac at its innermost end is found to be reflected upon the exterior of the contained body, forming a coating for it. When this body is examined by section it displays in its interior a fine tube which is continuous with the testicular convolutions, *d*, at the internal extremity, and at the other opens near the apex, *e*, of the egg-shaped body above mentioned. This body is formed then of a reduplication of the wall of the sac that opens at the external orifice, and contains the termination of the testis towards the exterior. It is capable of being elongated, drawn out to a point, and protruded altogether from the sac that contains it, and the sac itself is also capable of being everted through the external orifice. The contracted egg-shaped body, and the sac in which it lies, on being thrust out externally, assume the form of a much-elongated and finely tapering penis, fig. 5 *a*, inclosing the excretory duct of the testis which opens at its apex. When the parts are contracted, this penis forms the internal conical projection alluded to at the end of the general description.

The testis, fig. 1 *c*. This is a tolerably large tube, intricately convoluted in a somewhat zigzag manner, its coils bound together by a tissue of delicate filaments, and by the branches of the artery and nerve distributed to them, into a pretty compact mass, which lies in front of and upon the mucus-gland, and against the right side of the buccal mass, partly concealing the penis. When the coils are all unravelled we have a tube of uniform diameter, the length of which in one specimen was two inches, being greater than that of the animal itself. It is of a pale flesh colour and opake; and if a portion be removed and examined in the compressorium of the microscope, its walls are seen to be made up of three concentric coats; the two outer are muscular, and their fibres are longitudinal and transverse; the innermost is a secre-

ting membrane, and is lined by numerous corpuscles similar to those in the expressed contents of the tube.

The contents of the tube are easily pressed out, and consist of a tenacious mucus-like matter that contains a great number of corpuscles of different size and appearance, fig. 9. These are chiefly delicate transparent cells, some of considerable diameter, perfectly circular and having a double outline. They are of three kinds: 1st, those which are devoid of contents and of nucleus, fig. 9 *a*; 2ndly, those which present a large granular nucleus, which is either within and lying close upon the wall, or projecting about half their diameter beyond it, *b*; and 3rdly, those which are more or less completely filled with circular, granular and unnucleated corpuscles, *c*; these corpuscles are also seen in considerable numbers, *d*, free, of various sizes and apparently undergoing development into cells.

Spermatozoa have been observed among the contents of the testis of *E. coronata*, though we have not been able to detect any relation between them and the nucleated cells above described.

The tube of the testis after the unravelling of its coils can be traced a short way backwards, along the fissure between the lobes of the mucus-gland, where, after undergoing a sudden and remarkable constriction, it opens into the oviduct where that tube is abruptly bent upon itself, figs. 1 & 2 *k*.

The penis of *E. coronata* when exserted differs from the elongated conical organ of *E. papillosa* in being much bulkier in proportion to the size of the animal, and in its extremity being much enlarged and terminated by an almost circular fungiform membranous expansion, near the anterior border of which the excretory duct of the testis opens. This peculiarity appears to be accounted for by the modified form of the duct leading to the spermatheca in this species, and will be again noticed further on. The testis, fig. 3 *c*, differs also from that of *E. papillosa* in being very short, but of much greater diameter. The constriction at the part where it joins the oviduct is more strongly marked, and prolonged like a small duct. Fig. 8 represents the penis of *E. coronata* retracted within its sheath in the interior of the body.

The penis of *E. Drummondi*, fig. 6 *a*, is similar to that of *E. coronata*, and is given from a specimen preserved in spirits, in which it was exserted. The testis, fig. 4 *c*, is somewhat shorter and thicker.

The male organs of *E. olivacea* resemble those of *E. coronata*.

2nd. Female organs: the position and general appearance of the ovary, fig. 1 *d*, have already been described. On further examination the organ is found to be intersected by a longitudinal median fissure, which can be traced deeply into its substance, and which divides it into two principal lateral masses; smaller

fissures, offsets from the chief one, pass away laterally into the masses subdividing them into numerous lobules of varying form and size. The lobules are connected together by fine filamentous tissue, in which lie the branches of the oviduct and of the ovarian artery. Each lobe is invested by a delicate membrane, and appears to consist entirely of a congeries of ova inclosed within very delicate irregularly-shaped polygonal cells. Pl. IV. fig. 1 *a* represents these cells with the ova at a very early stage of formation; *b*, ova somewhat further advanced; *c*, ova much more highly developed, showing the germinal spot surrounded by the pellucid zone.

The ovary is attached to the skin by what appears to be delicate cellular tissue, and here and there by fine but firm flat bands that seem to be continuous with the inner or muscular layer of the integument. Small tubes, which we think are veins, are also seen passing from the outer surface of the organ into the substance of the skin.

At the front of the ovary, the oviduct, Pl. III. figs. 1 & 2 *e*, resulting from the union of the lesser ducts from all the lobules, is seen to issue from the longitudinal fissure; it is there a minute opake tube, but soon dilates, and passing over the spermatheca is bent upon itself two or three times very acutely, being further considerably increased in diameter, *f*; after this it becomes rapidly diminished in size, *e'*, straight, and continued forwards along the fissure between the lobes of the mucus-gland, and dipping down it receives the constricted part of the testis near *k* as before mentioned, and is then suddenly bent back upon itself. After this it is joined by the duct of the spermatheca, *i*, and the tube resulting from this union turns immediately forwards, and after a short course bifurcates, as is shown at fig. 2 *m*; one branch, *n*, the shorter, dipping downwards, is lost upon the channel belonging to the right side of the mucus-gland, and into which channel it appears to empty itself as the termination of the oviduct; the other and longer branch, *i'*, is continued on to the third and smallest external orifice by the side of the female aperture, and appears to be the channel of the spermatheca. This latter branch we have not been able to trace so satisfactorily as the rest, but have no doubt of its existence as described.

We now come to the large semipellucid or mucus-gland previously mentioned, figs. 1 & 2 *g g*. An analogous organ exists in *Doris* and *Tritonia* which has been described by Cuvier as the testis. It appears on looking first at the upper surface to consist of two distinct glands, but on the under surface these are seen to be perfectly continuous with each other. It is more or less convex on all sides, but the upper surfaces are so inclined towards each other as to leave a deep fissure, in which are lodged, as be-

fore mentioned, the oviduct, the duct from the spermatheca, and the posterior termination of the testis. The whole surface of the gland presents to a certain extent the appearance of the cerebral convolutions of the higher animals; there is however a rounded portion *g'*, seen next the fissure on the upper aspect of the lobes when they are held asunder, that differs from the rest in being opake, granular-looking and of a flesh colour, but more minutely convoluted than the semipellucid portion, yet forming an integral part of it. The semipellucid part of the gland can easily be seen to be disposed in the form of hollow laminæ folded upon each other, and these on the upper surface have a zigzag arrangement. The cavities of the laminæ communicate freely with a wide channel in the interior of each lobe, and these channels unite to form a common tube *b*, which ends externally at the female orifice, fig. 2 *b'*, after having received the termination of the oviduct *n*. This gland we believe not to be the testis, as Cuvier and his followers supposed it—for it has no direct connexion with the male parts—but to be the organ which secretes the transparent glairy matter that envelopes the ova previous to their passing from the body, by which they become attached to the substances on which they are deposited, and which protects them from injury during their evolution. On examining the secretion of this gland by the microscope we found no spermatozoa, but instead, a tenacious granular-looking fluid, with broad nucleated granular scales of what seemed to be pavement epithelium.

The ovary and other female parts do not appear to differ materially from the above description in *E. coronata*, *E. Drummondi* and *E. olivacea*.

3rd. Androgynous apparatus: the spermatheca, figs. 1 & 2 *h*, lies in front of the ovary between the two lobes of the mucus-gland, and is almost concealed from view by them and by the dilated convoluted part of the oviduct. It is a globular or pyriform sac, of a dirty olive colour, having one or more accessory sacs, *j*, attached to its duct; its walls are thin, but strong and muscular. In *E. papillosa* and *E. coronata* it has been found crammed full of a mass of fully-developed spermatozoa and corpuscles. The spermatozoa, fig. 10 *a* & *b*, consist of a narrow elliptical transparent head often bent upon a long slender tail or filament, which is seen to be either straight or waved, or spirally rolled upon itself. The corpuscles, *c*, are small, elliptical, and varying in size, many of them having a transverse band, others a cross upon them, apparently indicating a tendency to split into two or four parts as represented in the figure.

The duct of the spermatheca, *i*, comes off from the under and anterior part, and after a very short course forwards empties itself into the oviduct at *l*, fig. 2, appearing to end there, but in

fact continued on in union with it to the bifurcation *m*, where it separates from it as the smaller branch which goes on to the external genital orifice.

In *E. coronata*, *E. Drummondi* and *E. olivacea*, the female parts we have seen agree with those of *E. papillosa*; the male parts we have shown differ materially, and the androgynous apparatus again presents corresponding modifications in these three species.

The spermatheca in *E. coronata*, fig. 3 *h*, is a simple elongated pyriform sac without any accessory.

In *E. Drummondi* it is a sacculated bag. The ducts connecting the spermatheca, the oviduct and testis together in these species have the same disposition as in *E. papillosa*, but the duct which leads from the spermatheca to the external orifice is very much modified. It begins externally by a large orifice leading into a short wide channel with thick and wrinkled walls, figs. 3 & 4 *j' j'*, into the side of a strong globular sac *j j*; from the opposite part of this sac issues a minute canal *i' i'*, which returns along the external wall of the wide channel, and approaching the testis near its union with the oviduct, passes under it and between it and the penis, and then after a short tortuous course backwards it unites with the duct of the spermatheca near *i*, a little *above*, and not, as in *E. papillosa*, *below*, the junction of the latter with the oviduct.

The great size and peculiar modification of the external portion of the channel just described has reference obviously to the modified size and form of the intromittent organ in these species. We feel little doubt that the penis passes along the wide channel into the globular sac, which from its size and form is well-adapted to receive and probably to retain the expanded extremity of that organ.

This part of the apparatus is then a peculiar vagina; it is possible that a small point may be protruded from the orifice of the penis, fig. 6 *c*, at the time of conjunction; but whether this be so or not, we believe that the seminal fluid is conveyed along the minute channel, fig. 3 *i' i'*, we have noted as passing off from the vaginal sac *j*, and is thus delivered into the spermatheca *h*.

Looking at the remarkable shortness of the testicular tube in *E. coronata*, *E. Drummondi* and *E. olivacea*, in reference to the modification of their copulative organs, we suppose that the deficient development of the essential is compensated for by an increased efficiency of the accessory organs, that a more prolonged union of the sexes is here rendered necessary, and the conditions for this we find in the peculiar form of the penis and the vaginal sac.

In *E. papillosa*, on the contrary, copulation is effected by the

introduction of the elongated, conical and pointed penis, fig. 5 *a*, into the small simple channel of the spermatheca, fig. 2 *i'*, along which we believe it to pass to at least beyond its junction with the oviduct, if not quite to the spermatheca itself. The penis, as represented in the Plate, is from a specimen preserved in spirits, but in the living state this organ is capable of taking a much more elongated and attenuated form.

The way in which fecundation is effected will be understood if we now trace the passage of the ova from the ovary to the external orifice: they pass along the oviduct, fig. 2 *e*, and are detained awhile in the dilated and convoluted part of it, *f*, probably to receive some necessary investment; after this they are conducted forwards to where the testis joins the oviduct at *k*; here they are subjected first of all to the influence of the seminal fluid of the individual itself, for there appears to be little or no doubt that the double muscular coating of the testis, *c*, is capable of driving its contents either outwardly towards the penis *a*, or if required, inwardly towards the oviduct *e'*. Ciliary motion may also assist in determining the flow of the seminal fluid in either direction. The operation of this self-fecundation being thus accomplished in the first instance, the ova are secondly conveyed backwards to the duct of the spermatheca at *l*, where they undergo the action of the semen injected into that receptacle from another animal during the sexual union; afterwards they are carried into the right duct of the mucus-gland at *n*, which is freely continuous with the left duct, and with the common female channel of outlet *b*.

In the wide ducts of the mucus-gland the ova receive their last coating and their peculiar arrangement in it, and lastly they are expelled through the female orifice *b'*, the form of the channel probably impressing upon the continuous strap or cord of mucus-enveloped ova the peculiar form which the spawn of the different species is found to possess.

It will thus be seen that a double impregnation is here possible, and indeed more than probable, considering the anatomical relation of the parts; but whether it be in every instance essential, we are not prepared to state. If the experiments of M. Alex. de Nordmann related in the 'Annales des Sciences Naturelles,' 3me série, tome v. 1846, touching the breeding of *Tergipes*, which we consider a member of the genus *Eolis*, be thought conclusive, it may be deemed that self-impregnation is alone requisite. Since however copulation is observed to take place among these animals frequently and freely, even in confinement in the house, we have little doubt of the necessity of a double impregnation.

On a review of our description of the generative organs in the above-mentioned species of *Eolis*, it appears that these organs

bear a good deal of resemblance to those of the other Nudibranchiata as described by Cuvier; but in assigning the peculiar functions of the various parts, we differ from that distinguished physiologist. It is however only after often-repeated careful dissection, observation and deliberate consideration that we venture to dissent from such high authority, and we feel it incumbent upon us to state generally in what points we differ, and the reasons of our dissent.

That part in *Doris* called by Cuvier *testis* answers to what we call the *mucus-gland*: that it is not testis we are assured, by its having no direct connexion with the male parts, but opens very evidently into the female channel, of which it is an appendage; we have several times examined its secretion, and found it to correspond exactly with the mucus-like matter that envelopes the ova. Again, the convoluted tube, called by Cuvier *penis*, we believe to be the testis, and for the following reasons:—1st. It is not uncommon to find the true penis, exserted in specimens preserved in spirits: on examination of the parts of *E. papillosa* in such case, the penis of Cuvier is still found in the interior of the body as a closely convoluted tube, the coils of which are nearly all attached to each other by fine filaments, as noticed in our description, and are therefore not susceptible of being unrolled and made to act as an intromittent organ. A small portion however is freer than the rest, and is often found at the base of the penis, being prolonged also to its extremity as the excretory duct of the testis. 2ndly. Its internal structure and its contents are clearly those of a glandular organ, and spermatozoa have been found in it in *E. coronata*; and lastly, its connexions as already pointed out, namely with the penis at one end and with the oviduct at the other, seem to indicate pretty accurately its character.

The sac we have called *spermatheca* we have ventured so to name, because we find it possesses a channel of communication with the exterior and a direct connexion with the oviduct, besides containing, as we have witnessed in *E. papillosa* and *E. coronata*, abundant masses of densely packed spermatozoa. This organ is doubtless the "*vessie*" of Cuvier.

In passing from the Baron's description of the genitalia of *Doris*, while we are glad to acknowledge that his plates and descriptions have been of great service to us in confirming in many points the result of our own dissections, we cannot help being surprised that two other anatomists, who have so recently been engaged upon the corresponding organs of some of the *Eolididæ*, have not availed themselves of the store of valuable information accumulated by their illustrious precursor in the same path of investigation in his 'Mémoires pour servir' &c.—we allude to MM. de Quatrefages and de Nordmann. If we turn to the former

gentleman's account of the genital organs of his *Eolidina*, we find it to be very meagre and imperfect. He states at the commencement that these are as simple as possible; we have found them to constitute that part of the organization which is the most complicated and difficult to be understood. The copulative vesicle he mentions, which he thinks analogous to that of insects, and destined to receive and preserve the spermatic fluid of the *same* individual, acting the part in fact of seminal vesicle, and which he is tempted to believe renders the conjunction of two individuals unnecessary, seems to correspond to the spermatheca: the only other parts he mentions, the testis and ovary with their ducts, we find great difficulty in identifying with the parts described as such in our paper. That the congress of two individuals does really take place, we have had abundant proof.

In the latter gentleman's paper on *Tergipes* above-quoted, we have a confused but more detailed account of these organs. The Professor seems to have confounded the testis and ovary together, owing to the action of the compressor; for we cannot believe in the development of spermatozoa in the female parts, and in this we agree with his translator as well as in our conviction that the "*poches séminales*" are parts of a multiple testis. If this be the true interpretation then, we find that in this section of the genus there is a modification of the testis which does not exist, as far as we know, in any of the others. Such a modification we think not improbable, since we have observed a similar conformation in *Chalidis*, a naked mollusk having considerable affinity to the *Eolididæ*, and placed as the lowest genus in M. de Quatrefages' order Phlebenterata. The liver, as M. de Nordmann gives it, appears to be a part of the large mucus-gland we have described. The urinary gland is perhaps the opake granular part of the same. The testis is evidently the spermatheca, from its form and contents. The "*vessie muqueuse*" would seem to answer to the sac of the penis, and the short flexuous canal, which, coming from the *crytalloid* (?) bodies of the foot, enters its posterior extremity, appears to indicate the duct of the true multiple testis.

Organs of Circulation.

These are a heart and blood-vessels.

The central organ consists of auricle and ventricle with valves.

The vessels are arterial and venous.

The heart and the roots of the large vessels lie in the wide cavity of a delicate pericardium, Pl. IV. figs. 2 and 4 *f f*, *c c*; this is a very fine transparent membrane, difficult of detection at first, which is attached to the aorta just beyond its origin, and to the three great venous trunks just before their union in their common sinus, the auricle. At the same parts its external surface is

attached to the skin, and by means of these attachments the heart and great vessels are secured in their position. The heart and vessels thus inclosed lie free in the cavity, which they fill when fully distended with blood. The heart and pericardium lie above all the other viscera, and immediately beneath the skin of the back, on the median line, and just behind the anterior third of the body.

In *E. coronata* and those species which have the branchiæ similarly arranged, they lie between the second and third clumps.

They form during life a manifest elliptical elevation, more or less transparent, and in which the pulsations may be seen and counted.

On opening a specimen preserved in spirits, the auricle, fig. 2 *b*, is seen at the posterior part of the pericardium, of a cruciform figure, resulting from the union of two large trunks of veins *p p*, coming from the sides of the body with one, *q*, from the posterior part, lying along the median line; the anterior limb of the cross is formed by the contracted portion of the auricle *r*, where it goes forwards to open into the ventricle *a*. The walls of the auricle are quite smooth and polished externally, and within are formed of a very fine but wide meshed reticulation of delicate muscular bundles which are continued upon the greater venous trunks.

At the anterior contracted part is placed a valvular apparatus, fig. 3 *c*, the auriculo-ventricular, to guard the ventricular opening which is on the under surface of the heart.

The auriculo-ventricular valve consists of two flaps continuous at their bases with the walls of the ventricle and prolonged into its cavity, having their ends attenuated and free. They are placed one under and the other over the opening, the former being longer than the latter. They are broad and strong, and when brought together they will effectually close the opening. The opening is wide, and the auricle is attached to its margin at the bases of the valvular flaps.

The ventricle *a*, much smaller than the auricle, is of a pyriform shape, with its apex anteriorly. Its walls are considerably thicker and more fleshy than those of the auricle, and its cavity displays very numerous, strong and bold projecting carneæ columnæ, some of which are attached to the bases and outer surfaces of the valves at both orifices. The interior of the ventricle from its high development reminds us forcibly of that of animals much higher in the scale. The upper half of the organ is much thicker than the under, owing to the superior number and strength of its fleshy columns. The muscular fibres of the auricle and ventricle are devoid of transverse striæ; they are minute, simply granular and rounded.

A valve, the aortic, fig. 3 *d*, is placed at the anterior or pointed

end of the heart; it is a broad elongated lamina, very thin at its free edge, which is slightly semilunar. It projects a long way into the aorta. Its base is continuous with the fleshy columns of the upper wall of the heart, and just above this connexion, and behind the valve, there is a large well-marked sinus at the commencement of the aorta.

The aorta, fig. 2 *d*, begins at the base of the valve, and very soon after perforates the pericardium before giving off any branches.

The elliptical swelling and the transparency observed in the cardiac region during life is mainly owing to the dilated state of the two chambers of the heart. After death the fulness is lost, and the chambers are found contracted and flattened. With some care we have succeeded in a dead specimen in partially inflating the auricle by means of a small blowpipe, so that the parts resumed a good deal of the appearance they present during life. Fig. 4 represents the chambers of the heart inflated, imitating the condition of the parts during life*.

In *Eolis* then we have a simple two-chambered heart, the blood coming from veins into the auricle, passing then into the ventricle, and being thence propelled along the arteries. The pulsations are regular, and their number in *E. papillosa* is upwards of fifty, and in *E. coronata* sixty-five in the minute. The systole of the auricle is followed immediately by that of the ventricle, and during the former action the heart is pulled sharply backwards, during the latter forwards, showing the heart to be free in the pericardiac cavity.

The aorta on emerging from the pericardium gives off a small branch *e*, for the supply of the stomach, and immediately afterwards bifurcates; one branch, the larger, passes forward to supply the anterior parts of the body, the other backwards to be distributed to the posterior parts.

* That what we call the auricle is really such, and not a mere sinus or confluence of veins *branchio-cardiac*, as set forth by M. Milne Edwards in his 'Voyage en Sicile, sixième article, sur l'appareil circulatoire des Thétys,' we believe for the following reasons. It is distinctly divided from the great venous trunks by the pericardium which is evident enough in *Eolis*, and strongly defined in *Doris*: during life, or if injected after death, it presents a well-marked elliptical ampulla within the pericardium, and possesses a pulsation proper to itself, a pulsation that is seen during life to be confined within the bounds of the pericardium, and as if in confirmation of this it is found to be furnished with carneæ columnæ proportioned to the delicacy of its coats.

The branchio-cardiac sinus figured and described by Milne Edwards appears to us to be somewhat anomalous, and certainly differs from anything we have seen either in *Eolis* or *Doris*, and is quite at variance with the corresponding part in the *Tritoniadæ*, of which family it is clearly a member, for in *Tritonia Hombergii* and in *Scyllæa pelagica* the auricle is not longitudinally, but transversely placed, receiving veins from the skin at each end.

The anterior aorta, fig. 2 *f*, passing forwards over the genital organs, and on the right side of the stomach, but on a plane below the ramifications of the digestive system, gives off three or four small arteries, $e' e' e' e'$, to the stomach, and next from its under part a large branch *j*, which after sending off some small twigs is distributed by two or three branches which ramify on the penis, testis, mucus-gland and ducts. The main trunk, after this, is bent down in front of the genital organs, passes under the œsophagus, and becomes applied to the under surface of the buccal mass *n*, on the median line, after having given an offset, *k*, forwards to the anterior part of the œsophagus and upper surface of the buccal mass. Next, about half-way along the under surface of that fleshy organ, it gives off a large artery *l*, which penetrates its floor at an aperture left between the muscular bundles, to supply the tongue and the interior of the mouth: shortly after this, a branch springs on each side from the trunk; these encircle the anterior part of the mass of the jaws just behind the lips, supplying the muscles that connect the mass to the skin, and the skin itself in the vicinity. Lastly, the anterior aorta terminates in three branches near *m*, which are distributed by twigs to the lips and the anterior part of the foot.

The posterior aorta, f', runs a very short way forwards and then turns downwards and backwards, passing under the heart and gastric system; at this turn, and as it runs backwards, it gives off four or five branches to the rectum, which lies on its right side: one branch to the rectum is sometimes given off from the common aorta just after it has perforated the pericardium. The artery then gains the inferior surface of the ovary, among the lobes of which it is at first partially imbedded. On entering this viscus it at once gives off twigs right and left to the contiguous lobes; it next bifurcates, one branch passing on to be distributed by small lateral twigs to the middle and posterior lobes of the ovary, among which they can be seen to subdivide two or three times, accompanying the divisions of the oviduct; the other going to the skin of the foot under the ovary; seven or eight branches come off from it which penetrate the skin, and can be traced a little way dividing in its substance.

Thus we can demonstrate arteries supplying almost all the viscera and a great portion of the skin of the foot, and show that they undergo minute division, and all the branches laid down in our Plate have been verified by repeated dissection: we have failed however in making out their mode of termination. We cannot undertake to say whether they end by closed extremities, or whether they have open mouths which communicate with lacunæ or sinuses in the intervisceral spaces, or with those in the skin. The lacunæ among the viscera we have not been able to make out by dissection, and have not made use of injections

on account of the great difficulty of injecting such small animals, and from a feeling of the unsatisfactory nature of such an operation on tubes so delicate as the minute branches we have observed. The existence however of intervisceral lacunæ we do not wish to deny, since the valuable papers of M. Milne Edwards in the 'Annales des Sciences Naturelles' seem to establish the fact of their presence in nearly the whole of the Mollusca.

The branches of veins coming from the skin, represented in Pl. IV. fig. 2 *ssss*, have been several times verified; from four to six venous branches have been made out, uniting so as to form two large trunk-veins, fig. 2 *pppp'* and fig. 4 *eed'd'*, on each side, which joining together pour their united contents at once into the auricle: one of these veins can be seen along the inner aspect of the skin as far forwards as opposite to the transverse portion of the intestine, receiving branches, fig. 4 *gggg*, in its course from the skin, into which its most advanced branch penetrates; the other and much smaller vein turns backwards, and enters the skin sooner than the former, after visibly receiving a small branch or two from it. Entering the posterior part of the auricle is the posterior trunk-vein, fig. 2 *q* and fig. 4 *d*, which coming from the back part of the skin receives three pairs of branches at least: one pair appeared coming from below as if from the ovary, but was not so distinctly made out as the rest.

If we attempt to trace the veins into the skin, we find that they communicate with a system of sinuses therein. This network of sinuses pervades the whole of the skin, being abundant on the sides under the bases of the papillæ, and on the foot, and we suppose communicates freely with the system of intervisceral lacunæ pointed out by Milne Edwards. Whether the lacunæ of the skin have any thing like a symmetrical arrangement as principal trunks or canals, we have not been able to determine; but if a cross section of a papilla be made, a distinct canal becomes visible at each extremity of the section, as shown in fig. 6 *cc*, and from this and the symmetrical order of the venous trunks passing from the skin to the auricle, we might infer that such an arrangement exists. Those canals run the whole length of the papilla, and communicate with the meshes of a delicate cellular tissue which lines the skin of that organ; at the base of the papilla, they open into the sinuses of the skin. The position of these canals in the papillæ, and the cellular tissue in connexion with them, are indicated in Pl. IV. fig. 9 of our former paper on the digestive system.

The general course of the blood will be necessarily then from the ventricle along the arteries to the viscera and to the skin; in the first case it passes from the arteries, in a way we do not understand, into the lacunæ among the viscera and between them

and the skin, and thence into the network of sinuses in the skin itself, in the latter case into the tegumentary sinuses: in them and in the papillæ into which it is freely admitted; it is more or less perfectly aërated, and thence flows into the veins which pass from the skin to the auricle, and which are called by M. Milne Edwards *branchio-cardiac* vessels. From what we have observed however on attentively examining the connexions of the ovarium, we are inclined to think that the whole of the blood does not circulate in the way above described, for we are pretty sure we have recognized small veins passing away from the sides of the ovarium and entering the skin, and we mentioned above that we had, though indistinctly, made out a pair of veins running from the same organ to the posterior trunk vein that empties itself into the auricle. If these observations be correct, then a small portion of blood is returned to the heart in a way that forms an exception to the general rule, and the existence of veins distinct from the *branchio-cardiac* is established. These veins we presume must carry off from the ovarium to the heart and the skin the blood which has been supplied by the ovarian artery. In confirmation of these observations and of the inference drawn from them, we would add, that Baron Cuvier in his 'Mémoires,' &c. has described and figured in the anatomy of *Tritonia Hombergii* six veins passing from the mass of liver and ovarium into the skin of the side of the body, and conveying the blood to the branchial tufts; and having ourselves seen some time ago in the same animal similar vessels passing also from that mass to the skin, we are the more inclined to confide in the observations of the Baron.

Examinations of the heart of *E. coronata* have afforded the same results as we have detailed with regard to *E. papillosa*. We have succeeded in tracing nearly all the arteries in that species that were observed in the latter; but the venous tubes, from the excessive delicacy and high transparency of the parts, enhanced by the minuteness of the species, have hitherto escaped us. From frequent observations of the above organs in *E. olivacea* and several other species in the living state, we are confident that the circulatory system is as complete in these as in the previously mentioned species.

In M. de Quatrefages' account of the organs of circulation in *Eolidina*, the existence of the venous system is altogether negatived. The incorrectness of this observation we have already sufficiently proved. The two funnel-shaped auricular appendages of the heart described by him have been suggested most likely by a view of the anterior border of the auricle, and by some folding of the auricle itself or of the skin along the median line of the body. It is certain that the auricle is single, and that it

does receive trunks of veins on each side and behind,—trunks that result from the union of numerous venous branches of various size; that it does not communicate directly with lacunæ among the viscera is also certain; and that if we admit the existence of lacunæ, they do not supersede the venous system, but occupy the position of the capillary system of the higher animals. With regard to the arterial system, we can follow M. de Quatrefages with confidence only so far as the bifurcation of the aorta, and have not been able to discover the symmetrical division and arrangement of its branches as described in his memoir and figured in his plate, but we have succeeded in tracing many branches of arteries to a degree of fineness of which that gentleman seems to entertain no idea.

M. de Nordmann describes a ventricle and funnel-shaped processes, but besides these mentions an auricle; in other respects he seems to have fallen into the same errors as M. de Quatrefages: these errors seem due to the exclusive use of the compressor.

Organs of Respiration.

The function of respiration we believe to be performed by the whole surface of the skin, including the papillæ; the skin of the back and of the sides between the papillæ, and the entire surfaces of these latter organs, present the phænomenon of ciliary vibration*. The papillæ we regard as one modification among many of increasing the surface for a respiratory purpose, and thus are to be regarded as a specialized breathing apparatus, to which the rest of the skin is subsidiary.

The skin, Pl. IV. fig. 5, consists of a layer of muscular fibres covered by a tegumentary envelope or cutis that is provided with an epithelium.

The skin varies much in thickness in different parts, being thinnest over the back and on the papillæ, very thick where the papillæ exist; and it here contains near the external surface the ramifications of the digestive system, becomes much thinner suddenly where the papillæ cease along the sides, and attains on the foot its greatest thickness and strength. Its epithelium consists of very small granular nucleated particles, which during life are provided with vibratile cilia.

The outer or dermal layer of the skin, fig. 5 *b*, appears to secrete the abundant tenacious matter that exudes from the animal, and to be the seat of an exquisite sensibility; this layer is thin, but continuous with the next or muscular layer *a*, which

* Having recently, and since writing the above, discovered vibratile cilia covering the whole of the under surface of the foot of *Doris* and also of several of the testaceous Gasteropods, there can be little doubt that they are present also on the foot of *Eolis*.

might be called the cellular from its structure; this it is which varies so much in thickness. Next the visceral cavity there is a thin stratum of longitudinal and transverse fibres; outside of this is the membranous cell-work, containing sinuses that open into the trunk-veins going to the auricle.

The muscular coating in the papillæ is very delicate, and its fibres wider apart than in the rest of the skin, running longitudinally in bundles of two or three together at intervals, and transversely in fewer number and less regularly, as is represented in Pl. IV. fig. 9 of our previous paper.

The cell-work described as existing in the papillæ communicates freely with the system of sinuses mentioned as belonging to the skin of the body, and this system again we have traced to be continuous with the venous trunks leading to the auricle.

Under the compressor of the microscope we have seen, in the cellular layer of the papillæ, the blood move backwards and forwards to and from the base of the papillæ and into the skin, in obedience to the contractions of the body and of the papillary walls; but we believe, that if the animal were at rest and quite free, the action of the heart would also cause similar motions in the normal way. We look upon the contractions of the general integument and of the papillæ to be only accessory, not essential, to the perfect circulation of the blood.

Now the whole or nearly the whole of the blood that passes to the auricle of the heart comes, as we have shown, in the section on the circulatory organs, directly from the skin, and as we know that the blood thus circulating in the skin and papillæ is separated from the oxygenated water of the surrounding sea by a very thin layer, in the papillæ by an exceedingly delicate membrane, we have little hesitation in saying, that it is in the papillæ essentially, and in the rest of the skin secondarily, that the function of arterialization of the blood is carried on previously to the return of that fluid to the heart.

EXPLANATION OF PLATES III. AND IV.

PLATE III.

Fig. 1. General view of the generative organs of *E. papillosa* partially drawn asunder: *a*, sac of penis retracted into body; *b*, female channel; *c c*, testis; *d*, ovarium; *e*, oviduct; *f*, dilated portion of ditto; *e'*, continuation of ditto towards spermatheca duct; *g g*, transparent portion of mucus-gland; *g' g'*, opake portion of ditto; *h*, spermatheca; *i*, its duct; *j*, accessory glandule; *k*, confluence of testis and oviduct.

Fig. 2. Same organs more fully displayed: *a*, sac of penis; *a'*, male orifice; *b*, female channel; *b'*, female orifice; *c c*, portions of testis; *e*, oviduct; *f*, dilated portion of same; *e'*, continuation of ditto to testis; *g g*, pellucid portion of mucus-gland; *g'*, granular portion of ditto; *h*, spermatheca; *i*, its duct; *j j*, accessory glands; *k*, sudden angle

of oviduct receiving testis; *l*, point of union of oviduct with spermatheca duct; *m*, bifurcation of oviduct into channels going to external parts; *n*, short branch going to duct of mucus-gland; *i'*, long branch to external orifice, being continuation of spermatheca duct.

Fig. 3. Generative organs of *E. coronata* fully displayed: *a*, sac of penis; *b*, female channel; *c*, testis; *d*, ovary; *e*, oviduct; *f*, dilated portion of ditto; *g g*, pellucid portion of mucus-gland; *g'*, granular portion of ditto; *h*, spermatheca; *i*, its duct; *i' i'*, branch from it to vaginal sac; *j j'*, channel from exterior into vaginal sac; *k*, union of oviduct and testis; *l*, junction of oviduct with spermatheca duct; *m*, termination of oviduct in duct of mucus-gland.

Fig. 4. Portion of generative organs of *E. Drummondi*: *a*, sac of penis; *b*, female channel; *c'*, testis; *d*, oviduct receiving testis; *i i*, duct from vaginal sac to spermatheca; *j*, vaginal sac; *j'*, its channel leading to external orifice.

Fig. 5. Exserted penis of *E. papillosa*: *a*, penis; *b*, female orifice.

Fig. 6. Exserted penis of *E. Drummondi*: *a*, penis; *b*, female orifice; *c*, orifice of penis.

Fig. 7. Sac of penis of *E. papillosa* laid open: *a*, cavity of sac; *b*, its orifice; *c*, penis retracted; *d*, testis; *e*, orifice of penis.

Fig. 8. Sac of penis of *E. coronata* laid open: *a*, cavity of sac; *b*, its orifice; *c*, retracted penis; *d*, testis; e, orifice of penis.

Fig. 9. Contents of testis: *a*, *b*, *c*, different appearances of cells found therein.

Fig. 10. Spermatozoa: *a*, from spermatheca of *E. coronata*; *b*, two more highly magnified from *E. papillosa*; *c*, corpuscles associated with same.

Plate IV.

Fig. 1. *a*, cells of ovary containing very imperfect ova; *b*, *c*, ova in more advanced stages of development.

Fig. 2. Vascular system of *E. papillosa*: *a*, ventricle; *b*, auricle; *c c c c*, pericardium laid open; *d*, aorta; *e*, artery to stomach; *e' e' e' e'*, small branches to ditto; *f*, anterior aorta; *f'*, posterior aorta removed from body; *g*, ovarian artery; *h*, artery to posterior part of foot; *i i i*, branches to the intestine; *j*, artery to generative organs; *k*, œsophageal branch; *l*, branch to interior of buccal mass; *m*, continuation of aorta to mouth and anterior part of foot; *n*, buccal mass; *o*, œsophagus; *p p*, anterior lateral veins going to auricle; *p' p'*, posterior ditto; *q*, posterior median vein; *s s s*, venous branches to ditto; *r*, point of attachment of auricle and ventricle.

Fig. 3. Longitudinal section of heart of *E. papillosa*: *a*, interior of ditto showing carneæ columnæ; *b*, portion of auricle; *c*, auriculo-ventricular valve; *d*, aortic valve; *e*, aorta; *f*, sinus of ditto.

Fig. 4. Heart of *E. papillosa* inflated: *a*, ventricle; *b*, auricle; *c*, aorta; *d*, posterior median vein receiving lateral branches; *e e*, anterior lateral veins receiving branches, *g g*, from skin; *e' e'*, posterior lateral veins; *ffff*, pericardium laid open.

Fig. 5. Section of skin of foot and side of body of *E. papillosa*: *a a*, muscular or cellular layer; *b b b*, dermal layer or cutis with epithelium; *e*, side of body; *f*, foot.

Fig. 6. Transverse section of papilla of *E. papillosa*: *a*, hepatic gland; *b*, duct of ditto; *c*, large vascular canals; *d d d*, cellular tissue around gland.